CBNL
Cambridge Broadband Networks

ENSURING COST EFFECTIVE MMWAVE 5G DEPLOYMENTS

The importance of Microwave transmission in delivering the 5G vision

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1 INTRODUCTION & SUMMARY

The Commission's commendable Spectrum Frontiers action has quite rightly led to great interest in bands above 24GHz which are now being considered for deployment using new and innovative technologies and techniques that could not have been realized 5 years ago. It is against this background that CBNL wish to make comments regarding a number of issues of relevance in ensuring successful deployments which deliver the greatest benefit to Operators and End-users, whatever the resulting architectures.

Proposed 5G services bring with them significant challenges from both a technical and operational standpoint. Due to the large channel sizes required to deliver the proposed 5G capacities, focus has been on higher frequencies where such channels can be made available to operators expeditiously.

CBNL feel the push to make all frequencies above 24GHz identified in the Spectrum Frontiers Report & Order and the FNPRM available for Mobile use will lead to a significant lack of available spectrum for other services with alternative performance characteristics that ultimately will be key enablers in delivering the 5G vision. Specifically, Fixed FDD Point to Multipoint and Point to Point applications which offer significant capacity and range performance profiles will play an important part in the ecosystem are significantly disadvantaged under the emerging rules.

Such applications typically utilise paired FDD spectrum which have been historically allocated and harmonized via the ITU and associated regional bodies, leading to a large worldwide market of architecturally similar products in which Vendors can develop and manufacture at economic levels. It is these products that form the backbone of cost effective networks worldwide and provision must be made to allow access to paired spectrum bands that will provide operators with access to the latest Point to Multipoint and Point to Point technologies.

CBNL would also comment that the rush to higher frequencies at the expense of existing services offered in these bands leaves a significant gap in the capabilities. CBNL feel that the provision of high capacity medium range (1-3 miles) point to multipoint services will provide the most cost effective backhaul mechanisms for 5G services. The density of base stations required to deliver coverage to even a localized area with mmWave 5G is such that fiber deployment must become the exception rather than the rule. A rebalancing of Fiber vs Microwave/mmWave backhaul delivery for the delivery of cellular services in favour of Microwave is therefore likely and the current proposals make insufficient spectrum available in support of the existing Common Carrier bands.

CBNL therefore take this opportunity to provide additional information to the Commission regarding the successful deployments CBNL have enabled in the 28GHz and 39GHz bands as well as providing recommendations to enable support for the mid-range FDD services which will be required in delivering the vision.

2 ABOUT CBNL

Cambridge Broadband Networks Ltd (CBNL) is the global market leader in licensed point-to-multipoint (PMP) microwave and millimeter wave.

CBNL serves the world's largest service providers in 50 countries for backhaul, enterprise and residential fixed wireless, and smart city use cases. Our vision is to transform the microwave and millimeter wave market with disruptive carrier grade technologies that offer low cost and high performance to carriers and enterprise customers.

As the industry plans its 5G strategies, CBNL has a head start. CBNL's recent growth has been marked by its pre-5G commercial network deployments, bringing high capacity fixed wireless to tens of thousands of businesses and homes.

- Established in 2000
- Market leader in licensed PMP with more than 150,000 units deployed
- Serving 100+ communication providers across 50 countries
- World leading knowledge and skills in microwave and millimeter wave
- Strategic partnerships with nationwide spectrum holders
- Over 15% of revenue spent on R&D
- Backed by global investor syndicate
- 47 patents worldwide and all in-house development

3 ABOUT VECTASTAR

CBNL's VectaStar licensed PMP technology works by creating wide area sectors of carrier-grade coverage from single hub sites. Multiple subscribers can be served by single sectors that enable equipment, spectrum and site rental costs to be amortized across a number of links. The savings on site rental are particularly significant because this can represent up to two thirds of the lifetime cost of a wide area network (typically three times the cost of the initial hardware investment as identified in Ericsson's Microwave Towards 2020 Report).

This architecture results in a very quick time to market and drives significant efficiencies in the use of equipment and spectrum. The reduction in equipment at the hub site also plays a vital role in reducing the cost and burden that is typical for licensed PTP architecture and can help streamline the process of deploying new layers of coverage which is evidenced by the rapid deployments of the technology across the United States since 2014.

VectaStar uses frequency division duplexing (FDD) in order to create a fundamentally symmetric throughput, and to implement distributed interference avoidance. This architecture removes the need for complex coordination with systems operating in adjacent channels, and also minimises the self-interference that prevents (typically uncoordinated) WLAN-originating systems from scaling to cover wide areas efficiently.

In addition, VectaStar's µ-TDMA dynamically provisions capacity to those subscribers' sites that need capacity the most at any given instant. This increases spectral efficiency, enables Operators to offer more customers high capacity fixed wireless from the hardware investment and drives greater network ROI. The combination of dynamic µ-TDMA with FDD allows networks to be scaled from a single sector to 100s of sectors across an urban area, reaching total network capacity of 100s of Gbps, all with no loss of efficiency due to interference.

3.1 Current Product Characteristics

CBNL currently offer 3 variants of the VectaStar Platform at 28GHz & 39GHz specifically for the US market which offer Operators and Spectrum holders the ability to effectively match product variant to available spectrum.

Utilizing frequency-division duplexing (FDD), each VectaStar access point offers symmetric 275Mbps uplink and 275Mbps downlink to each sector from a pair of 50MHz channels, creating a total sector capacity of 550Mbps.

Sector capacity can be doubled to 1.1Gbps through deploying an additional access point to the sector in a 2+0 configuration. A VectaStar 2+0 sector deployment, such as this, requires two 50MHz channel pairs.

However, CBNL has developed proprietary medium access control firmware that has pushed spectrum efficiency beyond the previous state of the art. By directly multiplexing the high frequency spectrum with dynamic µ-TDMA, VectaStar offers significantly more rapid and accurate adaptation to the varying data loads of multiple endpoints.

This highly responsive system maximises statistical multiplexing gains and spectrum reuse, enabling VectaStar be overbooked without degrading the quality of experience. For example, with typical commercial data traffic, VectaStar can be overbooked by a factor of 4:1, to offer 4Gbps of sellable capacity per sector from two 50MHz channel pairs – four times more efficient than PTP. At this level of overbooking, there is no perceptible effect on customers' provisioned data rates. Higher levels of overbooking, appropriate to lower grades of service, such as residential ISP, can also be implemented for these scenarios.

The overbooking ability of VectaStar increases the ability for Operators to serve more customers with faster broadband speeds, whilst also improving the overall network business case. Figure 2 outlines the significant capacity available from the VectaStar that is commercially available today, alongside the capacity enhancements that will come to market through the next generation platform.

3.1.1 28GHz LMDS A1

The VectaStar 28GHz A1 Product offers full band coverage of the LMDS A1 Band, giving 8 discrete 2x50MHz channel pairs, each offering 550Mbps aggregate capacity (275Mbps Downlink + 275Mbps Uplink) with an effective range of up to 5 miles. The system is a Full Duplex platform and employs a T-R spacing of 450MHz.

ODU Type	Sub Band	AP Tx Range	RT Tx Range
VS600 A1	HBDH	28098-28350MHz	27648-27900MHz
	HBDL	27648-27900MHz	28098-28350MHz
	LBDH	27950-28202MHz	27500-27752MHz
	LBDL	27500-27752MHz	27950-28202MHz

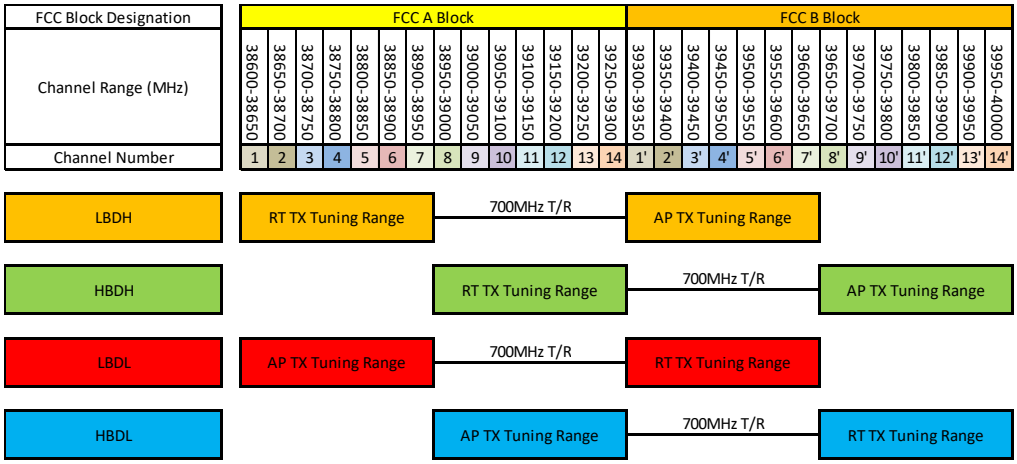
3.1.2 28GHz LMDS A1-A2

The VectaStar 28GHz A1-A2 Product offers split band coverage of the LMDS A1 Band and A2 bands, giving 3 discrete 2x50MHz channel pairs, each offering 550Mbps aggregate capacity (275Mbps Downlink + 275Mbps Uplink) with an effective range of up to 5 miles. The system is a Full Duplex platform and employs a T-R spacing of 1008MHz which is the internationally allocated T-R spacing in this frequency band.

ODU Type	Sub Band	AP Tx Range	RT Tx Range
ODU-S & VS600 A1/A2	HBDH[1]	29100-29250 MHz	28092-28242 MHz

3.1.3 39GHz

The VectaStar 39GHz Product offers full band coverage of the 39GHz Band, giving 14 discrete 2x50MHz channel pairs, each offering 550Mbps aggregate capacity (275Mbps Downlink + 275Mbps Uplink) with an effective range of up to 3.5 miles. The system is a Full Duplex platform and employs a T-R spacing of 700MHz.



Notes:
FCC Channels Pair a single A Block Channel with a corresponding B Block Channel.
In the above table Channel 1 pairs with Channel 1' (1-1'), thru Channel 14 with Channel 14 ' (14-14').

4 CURRENT USAGE OF 28/39GHZ BANDS

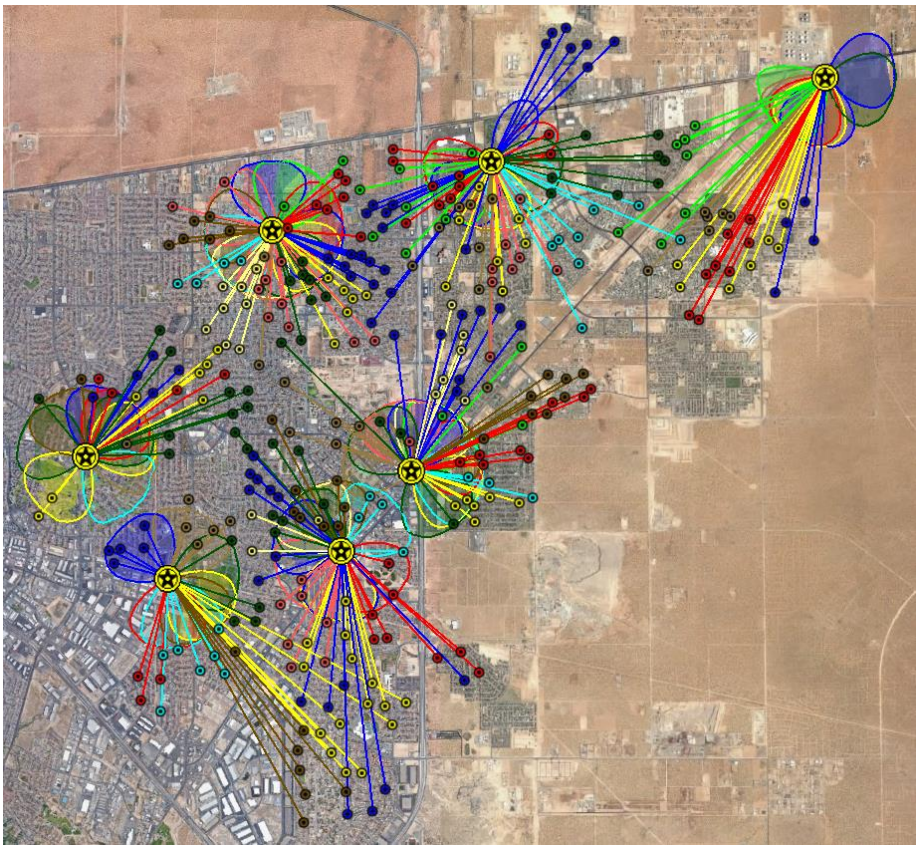
Since the introduction of the VectaStar platform to the United States in 2014, CBNL's Customers have successfully deployed in excess of 7000 Subscriber terminals in operation across major markets within the United States, operating in the 28GHz A1, 28GHz A1/A2 and 39GHz bands. These deployments offer Operators the ability to provide high speed, disruptive services to areas typically underserved by incumbent DSL/Cable operators and form a valuable part of the United States Telecommunications mix. Over the past 3 years, CBNL's Customers have made significant investments in both technology and spectrum acquisition within these bands and CBNL would urge the FCC to ensure that any rule changes be cognizant of these users by ensuring provision for ongoing use.

4.1 Existing Deployments

CBNL's Customers have deployed thousands of 28GHz & 39GHz systems within the United States since 2014 and CBNL are, at the time of writing, the largest deployed Vendor of FDD Point to Multipoint equipment in these bands. To date, CBNL's Customers have deployed over 7,000 links serving over 35,000 businesses and residential homes (as a subscriber terminal offers software-defined virtual interfaces, each terminal may serve many individual end users, each with potentially differing carrier-grade SLAs, and with no cross-talk between users).

The rapid adoption of CBNL's technology has been enabled in large part to the platform's capability to offer significantly greater coverage from a single base station than that envisaged by the upcoming 5G NR platforms resulting in a far lower cost to deploy and with no technology risk associated.

A typical High Density 28GHz Deployment is shown below, covering approximately 100 square miles and with the capability to deliver ubiquitous line of site coverage with capacities in excess of 500Mbps aggregate. A typical 5G NR deployment is likely to require a significantly greater number of base stations to cover the same area



5 CBNL OPINION AND RECOMMENDATIONS

As one of the only Vendors with equipment available within the 28GHz & 39GHz bands whose Customers will be most significantly affected by the Report and Order and associated FNPRM, CBNL offer the following observations and recommendations for those and other bands under consideration.

5.1 FLEXIBLE DUPLEXING RULES

Regarding the relative merits of TDD and FDD per se, while being in favor of the flexible duplexing rules that other commenters “overwhelmingly support”, CBNL also offer the following comments:

To date, FDD operations predominate in licensed wide area operations. This is largely due to the simplicity of interference avoidance afforded by such a system design, both for a single network operator with a multi-cellular network and for multiple, collocated network operators using adjacent channels.

One may regard the T-R spacing and front-end filtering of an FDD system as being a way to implement, in a distributed way, an interference avoidance function. By contrast, without temporal coordination of T-R scheduling, collocated TDD systems in adjacent channels will mutually interfere with one another. Implementing this temporal coordination adds complexity to the TDD system and constrains the variation of uplink/downlink ratios, often cited as a principal advantage of the TDD approach. We note that such coordination may be difficult or impossible to achieve where differing, mutually incompatible, systems are deployed in adjacent channels.

If a transmitting TDD system is constrained not to cause interference to an unsynchronized, collocated receiving TDD system in an adjacent channel (as is likely in the allocation scenarios being considered), the necessary filtering to give the required isolation will, in a practical realization, reduce the available channel bandwidth to a significant extent. (Comparatively, in an FDD system, the receiving channel is separated from the transmitting channel by the T-R spacing, so the filter roll-off can be ‘spread’ across a large bandwidth).

Finally, we note the difficulty of coordination between a TDD system and an FDD system. Because an FDD system transmits continuously on one frequency, there is no way to arrange a spectrally adjacent TDD system’s T-R schedule such that it does not suffer interference when trying to receive. Likewise, when a TDD system is in use adjacent to the receive channel of an FDD system, there is no way to arrange the T-R schedule of the TDD system such that the FDD system does not suffer interference.

While licensed bands with flexible duplexing rules do exist worldwide, we are not aware of any such bands where both TDD and FDD systems have been deployed at a commercial scale. Given the amalgamation of the 37 and 39GHz bands, it may be prudent to allocate TDD channels upwards from 37GHz and FDD channels downwards from 40.0GHz, to allow the greatest scope for harmonious coexistence.

CBNL would therefore urge the Commission and all parties to work together to establish the true level of interference and co-existence possible within bands prior to sterilisation in favour of one technology over another.

5.2 Protecting existing users

Given the wide reaching impacts of the NPRM and FNPRM regarding these matters, CBNL believes the risks to its Customers who are incumbent users of the band have not been fully appreciated and respectfully recommends the consideration of the following actions to protect their investment in deployed systems:

5.2.1 Where Licenses have been maintained under the previous rules:

Where existing licenses have been maintained and equipment deployed, CBNL advocate that Operators using these bands be allowed to continue operations post implementation of the band structure changes. Any spectrum transaction where incumbent users are identified as affected should

be reviewed by the Commission to ensure appropriate treatment of those users by spectrum asset owners.

5.2.2 Where band changes will materially affect existing/expanding users

Where existing licenses are considered for material alteration at the request of the Spectrum Owner (for example in the 39GHz band whereby an existing FDD paired spectrum raster is replaced by an unpaired 200MHz raster favouring TDD) that incumbent users who have invested in equipment to deploy in these bands be afforded sufficient time to transition to alternative solutions prior to spectrum transactions being approved by the Commission.

5.3 Band Specific Comments and Recommendations

5.3.1 24GHz : FCC 16-89-385

CBNL advocate the continued use of this band in an FDD supportive structure. The FCC's recent law making in bands above 24GHz has focused on making large contiguous blocks of spectrum available to 5G operators for access networks, however in doing so, the available spectrum for Fixed links (be they for Fixed Point to Point or Point to Multipoint) has been significantly diminished. CBNL therefore do not support the conversion of the band for unpaired use

Microwave backhaul, contrary to the popular view, lies at the core of nearly every modern network due to the high cost and relative unavailability of fibre based backhaul solutions. This will become even more critical due to the extremely high base station density that 5G NR technologies will require and provision of suitable paired spectrum for low latency, high capacity backhaul links is a key enabler to the successful deployment of 5G solutions.

5.3.2 28GHz A1 : FCC 16-89-72/184

The Commission have ordered that incumbent LMDS A1 license holders receive 2x 425MHz blocks in lieu of the existing single 850MHz block, subject to compliance with the spectrum aggregation policies set out in 16-89 para 184.

CBNL believe that it is appropriate for existing licensees operating in the LMDS A1 band to be afforded recognition of their investment in prior deployments by allowing them to benefit from licence renewal under the terms of their existing LMDS licenses. This would have the effect of allowing any LMDS block deployment to satisfy the coverage and usage requirements and afford licensees the time to migrate their services over a longer period.

5.3.3 28GHz A2 :

In the Report and Order and associated FNPRM, the commission makes little reference to the 29.1-29.25GHz A2 allocation of the existing LMDS Licenses. Historically, this block formed an integral part of the spectrum mix for early Fixed Wireless services envisioned by the initial LMDS auctions. By pairing this block with the LMDS A1 spectrum, this allowed internationally harmonized products to be deployed in the LMDS bands whilst specific product based on the A1 band could be developed. Indeed, it is this variant that supported the introduction of CBNL's first products in the United States, being based on the highly successful international variant with over 150,000 terminals shipped worldwide.

As the A2 band consists of only 150MHz, it is not being widely considered for Mobile use and CBNL support this view but believe it to be of key significance in providing mid-range (1-5 miles) backhaul

services to ultimately support 5G deployments. By pairing the A2 block with the A3 or contiguous A3+B spectrum high capacity Point to Point/Point to Multipoint transmission systems can be deployed.

Allowing transmission from subscriber terminals in this band could allow new paired FDD services to be brought to market, alleviating some of the issues generated by the regulatory move away from FDD allocations and providing high capacity backhaul capabilities for 5G services. This application is being considered jointly by CBNL and a major Tier 1 Operator to provide backhaul for future 5G services with an estimated system capacity of in excess of 500Mbps achieved in a 50MHz channel.

5.3.4 28GHz A3 & B1, B2

In the Report and Order and associated FNPRM, the commission makes little reference to the 31.075-31.225MHz A3, 31.00-31.075MHz B1 and 31.225-31.30MHz B2 allocations. CBNL agrees with the Commission's position that according these bands mobile usage rights may be problematic and further suggests that they can provide refuge for FDD systems in the higher bands that have been ill catered for.

CBNL also petition the FCC to allow, where operators are in possession of LMDS A3, B1 and B2 allocations, innovative fixed use of these bands by allowing contiguous use of this spectrum paired asymmetrically with the aforementioned A2 band. In this circumstance, and with adoption of CBNL's recommendations for the 28GHz A2 band, products providing >800Mbps subscriber services could provide coverage to many square miles from a single base station in the same way as CBNL's current portfolio. This application is being considered jointly by CBNL and a major Tier 1 Operator to provide backhaul for future 5G services.

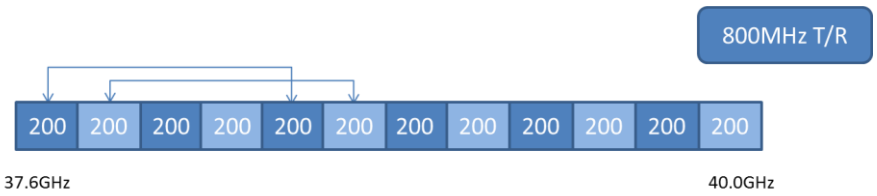
5.3.5 37.6-40.0GHz

CBNL are broadly supportive of the initiatives the Commission has undertaken at these frequencies, however we again note no arrangement has been made to accommodate existing FDD users within the band.

CBNL feel that it is appropriate to ensure access to FDD spectrum within any future auction. CBNL also note that these frequency bands are ubiquitously used for Point to Point FDD usage in most territories worldwide as they offer high capacity and range suitable for deployment in and around large metropolitan centers and should therefore form part of the Spectrum mix considered by the Commission.

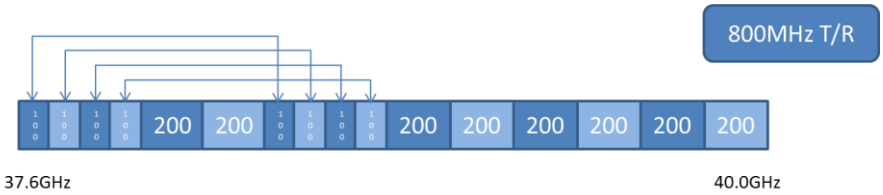
To that end, CBNL propose a system whereby a number blocks within the 37.6-40GHz raster be offered as paired blocks. This will allow Operators wishing to leverage the longer range capabilities of the band to do so whilst still affording those wishing to deploy 5G services the ability to acquire larger, contiguous spectrum holdings.

An example of a suggested 37.6-40GHz Raster:



The above raster provides proportional access to FDD spectrum whilst satisfying the need to provide multiple 200MHz blocks of spectrum which could be aggregated for 5G usage. CBNL would suggest that in the implementation of such a plan, that a minimum separation between paired blocks of 400MHz would be observed as this will result in lower development time and cost in bringing such products to market. In the example above an 800MHz T-R allows 2 adjacent 200MHz channels in the lower band and 6 adjacent 200MHz toward the top of the band.

This does however create a disadvantage for bidders requesting access to FDD based spectrum in that it would require acquisition of a minimum of 400MHz of spectrum to enable use (in contrast to the minimum 200MHz required for TDD operations). CBNL further suggest that pairing 100MHz channels would achieve the same aim and also make the auction consistent around 200MHz blocks of available spectrum. TDD bidders would naturally favour the larger channel sizes whilst FDD bidders would acquire 2x 100MHz channels suited to their requirement:



With regard to existing systems deployed in the 38.6-40.0GHz bands, CBNL would urge the FCC to ensure fair transitional arrangements are enacted by Spectrum owners in order to protect the investments made by our Customers, including if necessary granting appropriate benefits to incumbent users of the band in any upcoming auctions.

5.3.6 42-42.5GHz & 42.5-43.5GHz

In the FNPRM, the Commission notes requests for consideration of the 42-42.5GHz band for mobile use. CBNL, along with other commenters believe this to be unnecessary due to the large spectrum allocations already granted mobile users and the additional being bands considered under the FNPRM.

CBNL additionally supports the use of the 42.5-43.5GHz bands in a controlled manner for Point to Point and Point to Multipoint FDD systems and believe it to be feasible to co-exist with RAS users by use of proper frequency coordination and planning mechanisms. CBNL urges the commission to create FDD channelization in this band.

ITU-R F.2005 specifically creates an appropriate band plan for this band and would enable users to benefit from worldwide harmonisation benefits (low cost/broad equipment availability).

6 IMPACT OF REVIZED SUBSTANTIAL SERVICE OBLIGATIONS & SPECTRUM STOCKPILING

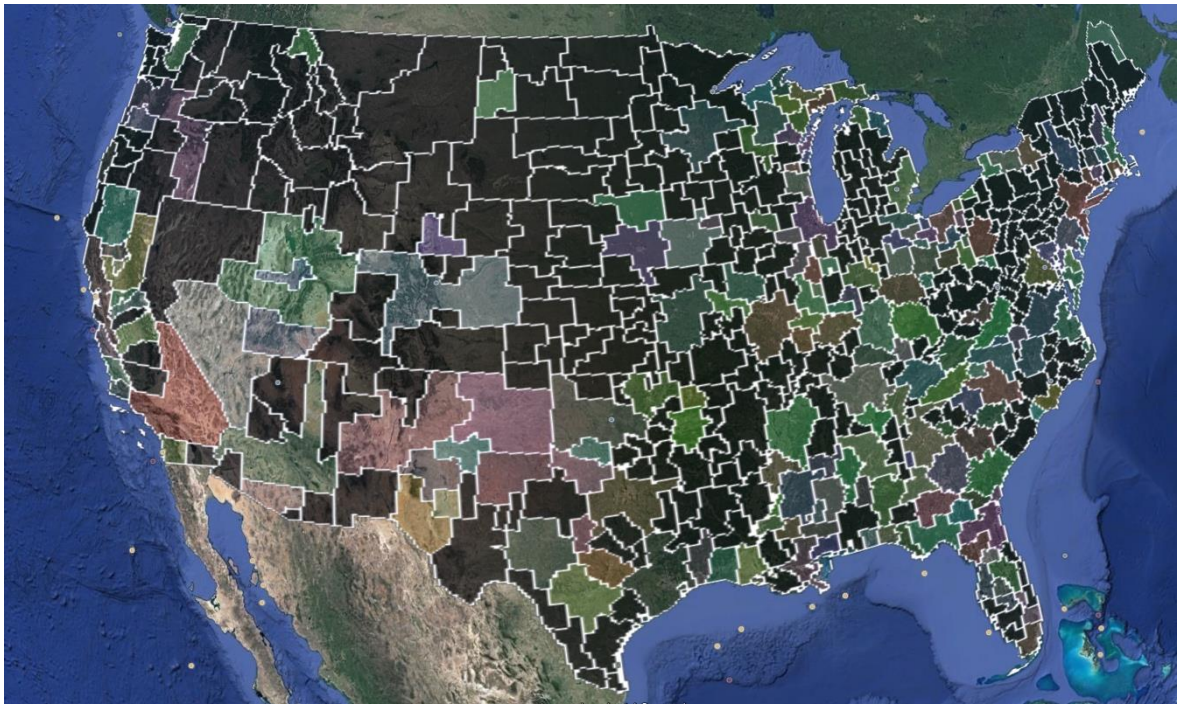
As part of the Spectrum Frontiers report and order, the Substantial Service obligations were significantly revized to allow deploying operators longer to reach their coverage obligations. From a technological standpoint, this will allow Research and Development activities to continue with the aim that suitable 5G equipment will become commercially and economically feasible within the timescales considered by the order.

Whilst the action to increase the build out timescales in which to meet the substantial service obligation is generally sensible given the immaturity of mmWave 5G technology, the reality is that many areas will not see the benefits of commercial mmWave 5G services until the mid 2020's. Naturally this also assumes hardware availability and deployment economics that can withstand the high cost of delivering networks with such small cell coverage.

CBNL further feels that the reduction of the coverage areas to PEA/County level will lead to large areas of the country where no usage will occur. This is will occur where effective range of the prevailing mmWave 5G technology is such that only areas with high enough population densities will be able to benefit from the technology, deepening the Country's expanding digital divide.

CBNL also draw attention to the previous auctions where it is evident that the focus of major Operators has been to deliver services in highly populated areas. Whilst this is clearly a commercially astute approach, the remaining allocations of active 28GHz LMDS licenses informs of the likelihood of spectrum being acquired but never deployed. Of around 500 BTA's initially licenced, less than half remain active.

2016 LMDS Licenses (Inactive in Black)



There is therefore a significant risk that areas that are not considered important for mmWave 5G services today may well be stockpiled for future deployments. These PEA's will likely not attract significant bid interest in auction, and therefore could be acquired for relatively insignificant amounts. CBNL believe this could encourage an aggressive acquisition and stockholding of 'non-prime' spectrum, precluding alternative use.

Further, given the differing performance characteristics of the various bands considered for Mobile service adoption, CBNL feel that allowing a single operator to monopolise a single frequency band may disadvantage

consumers due to the cost of deployment advantage afforded to holders of lower band spectrum, whose better propagation characteristics would mean a significant reduction in required base stations for a given area.

CBNL also believes that any licenses issued under these and future proceedings should be issued on a use-or-share basis, with sharing mechanisms as appropriate to facilitate access to smaller operators wishing to deploy, particularly in areas of low 5G activity and that appropriate mechanisms be implemented to ensure such. In areas where the incumbent has failed to meet their coverage obligations by the mandated deadlines, the Spectrum allocation should be rescinded and made available for other users.

7 CONCLUSION

It is evident that the technologies being developed to support the 5G vision are a significant departure from those that enabled the successful 4G leadership demonstrated by the United States. These technologies pose inherently greater risks to adoption due to the higher frequencies and therefore reduced propagation characteristics of these bands which will necessitate smaller cell coverage per base station and therefore significantly higher numbers of base stations per territory.

CBNL urges the commission to ensure that access to spectrum for Fixed and Mobile applications/technologies is enabled by fair, appropriate and timely allocation of spectrum to users, both incumbent and new. Spectrum allocations should take account of the differing characteristics of each band, the demands of potential users, as well as the availability of products both current and future. Spectrum should be allocated in large channel sizes supporting TDD where appropriate and in smaller, paired FDD configurations as has been articulated in this document.